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मानक

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IS 5050 (1992): Code of practice for design, construction and maintenance of relief wells [WRD 8: Foundation and Substructures]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक

विमोचन कूप का डिजाइन, निर्माण व रखरखाव की रीति संहिता
(पहला पुनरीक्षण)

Indian Standard

**CODE OF PRACTICE FOR DESIGN,
CONSTRUCTION AND MAINTENANCE OF
RELIEF WELLS**

(First Revision)

UDC 627·8·034·96 : 627·824

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BHADUR SHAH ZAFAR MARG
NEW DELHI 110002

February 1992

Price Group 8

AMENDMENT NO. 1 MAY 2011
TO
IS 5050 : 1992 CODE OF PRACTICE FOR DESIGN,
CONSTRUCTION AND MAINTENANCE OF
RELIEF WELLS

(First Revision)

(Page 1, clause 2.1, line 15) — Substitute ‘advances’ for ‘advance’.

(Page 2, clause 2.6, line 14) — Substitute ‘Actual observation after installation should be used to verify the adequacy of the designed spacing and sizes of relief wells.’ for ‘The adequacy of the designed spacing and sizes of relief wells by actual observation after installation should be verified.’

(Page 2, clause 2.6, line 20) — Substitute ‘four to five years’ for ‘four or five years’.

(Page 2, clause 3.4, line 2) — Substitute ‘one to two meters’ for ‘one or two meters’.

(Page 4, clause 5.3.1, line 5) — Substitute ‘assumptions are given’ for ‘assumptions given’.

(Page 7, Fig. 4B) — Substitute:

REFERENCE $r_w = 15 \text{ cm}$ ——— $r_w = 25 \text{ cm}$ - - - - -
--

for

REFERENCE $r_w = 15 \text{ cm}$ $r_w = 25 \text{ cm}$
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(Page 7, Fig. 5A, Vertical Axis) — Substitute ‘ $\frac{E_L}{a}$ ’ for ‘ $\frac{EL}{g}$ ’.

Amend No. 1 to IS 5050 : 1992

(Page 9, Fig. 6, PIPE DIA) — Substitute ‘4.5 cm’ for ‘46 cm’.

(Page 13, Annex B, first column, line 2) — Substitute ‘ $S = 100 \text{ m}$ ’ for ‘ S 100 m’.

(Page 13, Annex B, first column, line 3) — Substitute ‘ h_s ’ for ‘ H_s ’.

(Page 13, Annex B, first column, line 7) — Substitute ‘ $r_w = 15 \text{ cm}$ ’ for ‘ $r_w = 15 \text{ m}$ ’.

(Page 14, Annex B, first column, lines 1 and 2) — Substitutes

$$\therefore \frac{h_m - h_w}{h_s - h_w} = 1 + \frac{\log_e \frac{2}{1 + \cos h 2 j_s}}{2 \log_e \frac{e j_s}{j r_w}} = 0.1086 \text{ for the existing.}$$

(Page 14, Annex B, first column, line 6) — Substitute ‘which is less than 0.3 H ’ for ‘which is less than 0.34’.

(Page 15, Annex C, first column, line 4) — Substitute ‘ $h_s = 35 \text{ m}$ ’ for ‘ $H_s = 35 \text{ m}$ ’.

(WRD 8)

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Foundations and Substructures Sectional Committee had been approved by the River Valley Division Council.

Water-retaining structures, such as dams and levees are subjected to uplift if their foundations are pervious or comprise of stratified layers of pervious and impervious materials. Stability of these structures may be seriously impaired if uplift pressures are not controlled by:

- a) direct interception of seepage,
- b) pressure relief, and
- c) counter-balancing by loading berms.

Pressure relief can be afforded by installing under, or just near a structure, a drainage system to tap ground water under pressure and relieve the pressure by providing a path of low resistance.

In earth dams, uplift is usually controlled by providing a positive cut-off, up to impervious stratum, consisting of either bed-rock or a clayey material. However, this may not be possible where the overburden is deep and a compromise has to be usually arrived at, by providing a partial cut-off or upstream blanket and a pressure relief system, that is relief wells on the downstream side of the dam. Under appurtenant structures pressure relief can be obtained by providing sub-floor drains, relief wells, etc. Similar uplift relief-holes are provided under spillway aprons, head regulators, etc.

This Indian Standard was first published in 1968 and is being revised to incorporate provisions regarding the use of geofabrics as filters around screens and their design, installation of PVC rigid pipe relief wells, and diameter of relief wells.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

CODE OF PRACTICE FOR DESIGN, CONSTRUCTION AND MAINTENANCE OF RELIEF WELLS

(First Revision)

1 SCOPE

1.1 This standard covers design, construction, observation and maintenance of relief wells provided for earth dams resting on pervious soil foundations. The principles, however, may also be applied to other structures (such as spillway aprons, head regulators and other appurtenant structures) involving pervious foundations, where uplift pressures are likely to develop.

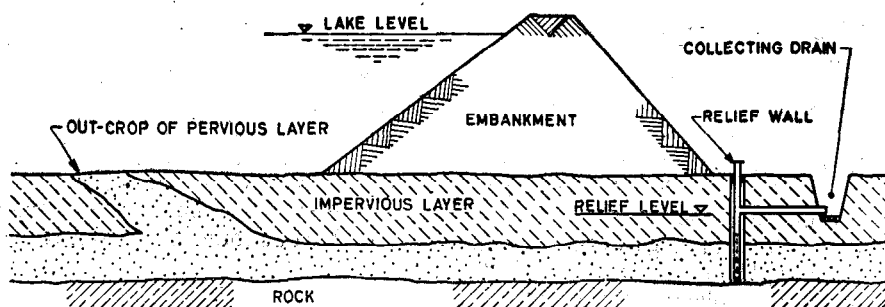
2 GENERAL PRINCIPLES AND UTILITY OF RELIEF WELLS

2.1 A relief well consists of a small drainage well (50 to 90 cm in dia) sunk near about the downstream toe of an earth dam, with a pipe (about 10 to 20 cm in dia) having narrow slots, placed in the centre and surrounded by graded filter media which permit the ingress of seepage water into the well allowing it to rise to the outfall (relief) level where the pressure gets relieved. The filter media has two main functions to perform. Firstly, to allow free passage of seepage water and secondly to arrest the migration of soil particles effectively. Uptil now, filter materials, that is sand and gravel, which are naturally available are being used. Due to advance in technology, it is now possible to use synthetic filters, like geofabrics, which are readily and easily available in the market. The advantage of utilising geofabrics is that the overall diameter of the relief well can be reduced to 20 cm or so which otherwise require a diameter of 59 to 90 cm.

2.2 To ensure safety of an earth dam in cases where the cut-off is partial, or reliance is placed on an upstream blanket for controlling underseepage, it is generally necessary to control the pressures developed below the downstream toe of the dam, especially if a pervious layer is overlain by an impervious layer of soil at the top. This may be effectively done by installing a system of relief wells, suitably spaced, which will reduce the intensity of the underseepage pressures and render the seepage water practically harmless whereafter it may be conveniently led to a natural drainage channel.

2.3 Relief wells are most effective in cases where a sort of artesian or subartesian condition prevails in the foundation strata below an earth dam, that is when a pervious stratum is sandwiched between two impervious strata and the pervious stratum somehow gets connected to the water in the reservoir which is at a high head, as indicated in Fig. 1.

2.3.1 In such cases a system of relief wells spaced at suitable intervals and penetrating either fully or partially (at least 50 percent) into the pervious layer may be installed to relieve the under seepage pressures developed in the pervious layer. As the pressures in the lower pervious layer get reduced, the exit gradient of water through the upper layer also gets reduced to a value much below the critical gradient, thus preventing likely erosion of soil particles.



NOTE — Pervious stratum sandwiched between impervious strata where relief conditions will be most effective.

FIG. 1 DAM ON PERVIOUS FOUNDATION IN ARTESIAN CONDITION

2.4 A system of relief wells is also effective when the foundations under an earth dam consist of alternate layers of pervious and impervious strata (or where sand lenses are encountered) as the relief wells penetrating through such strata would relieve the pressures locked-up in the pervious layers or lenses. Relief wells may also be used in foundations in which permeability increases with depth.

2.5 In case of foundations consisting of pervious material right from surface to impervious stratum like rock, relief wells may not be fully effective, the flow being distributed over the entire length and depth of the foundation. They however, serve their purpose in relieving pressures that may get locked up below some impervious pockets or where the horizontal permeability differs substantially from the vertical permeability. Hence, they should be generally provided in such cases, especially if the cut-off is only partial or upstream blanket only has been provided. Relying exclusively on partial cut-off or upstream blanket in such cases is not desirable and therefore, not recommended.

2.6 For proper functioning of relief wells, however, observation and checking of specific capacities of the relief wells from time to time after construction is of prime importance; otherwise they are likely to get choked with usage and may not function as desired. The spacing of relief wells is a matter of judgement and is to be checked by the procedure given in 5.3.3 to 5.3.6, however, the formulae given are only for guidance and may not be taken as absolutely accurate. There are limitations due to heterogeneity that may exist in the pervious media and concentration of seepage along some preferential paths. The adequacy of the designed spacing and sizes of relief wells by actual observations after installation should be verified. Relief wells are at times likely to get clogged due to lime accretion and need to be watched and checked at intervals after they have been functioning for four or five years.

3 RELIEF WELL COMPONENTS

3.1 The details of the usual type of relief well consisting of a metal pipe, preferably of non-corrosive type, slotted at intervals to allow water to enter the pipe and surrounded by graded filter media, to prevent soil particles from the foundation strata entering the pipe through the slots, are shown in Fig. 2. Brass and stainless steel are non-corrosive but very prohibitive in cost and, therefore, galvanized iron pipes may be used, though porous concrete pipes, wooden staves and even plastic pipes may be used whichever are more easily available. Use of dissimilar metals for strainer pipes, riser pipes, etc, should be avoided to minimize corrosion by electrolysis.

3.2 A relief well should generally be about 50 to 90 cm in diameter, depending on the underseepage pressures anticipated, and the drilling equipment available. The slotted pipe to be placed in the centre should have a minimum internal diameter of 10 cm and up to 20 cm, if the flows expected are larger. Sufficient annular space (at least 15 cm should, however, be kept between the pipe and the drill hole to facilitate the pouring-in of the graded filter media around the pipe. If the foundation strata consists of fine sand (or coarse silt), the filter media may have to be placed in two annular layers. In such cases sufficient annular space (20 cm minimum all round) should be kept so as to permit placing the double layer filter by a specially designed tremie.

3.3 Slots should be provided only in those portions of the pipe which pass through the pervious layers of the foundation. In the impervious layer portions, blind-pipes should be provided. The annular space between the relief pipe and the drill-hole should be filled with graded filter media which should satisfy the filter criteria (see 5.5.2) with the surrounding soil as well as with the slots. The filter should be laid up to about 120 cm above the top of the slotted length so as to prevent fines from entering into the well and choking it. At the surface, where there is usually impervious soil, the pipe should be a blind one and the annular space back-filled with impervious soil or cement-sand mortar, with some addition of bentonite, to prevent an upward flow of water outside the pipe, that is through the graded filter media.

3.4 The relief well should have a relief level or discharge level one or two metres below the ground level from where the underseepage water could be carried away by a well-laid surface drainage or pipe-drain system. However, no criteria can be laid down for fixing the relief level and it may be decided by the designer taking into account field conditions, such as availability of outfall and depth of overburden. In the river gorge portions, relief levels may be fixed with due regard to the normal flood level or back-water expected in the river after construction of the dam. The outfall pipes may be fitted with non-return valves and placed slightly above the normal flood level to eliminate possibility of silt depositing in the relief well. In such situations, a loading berm should be provided.

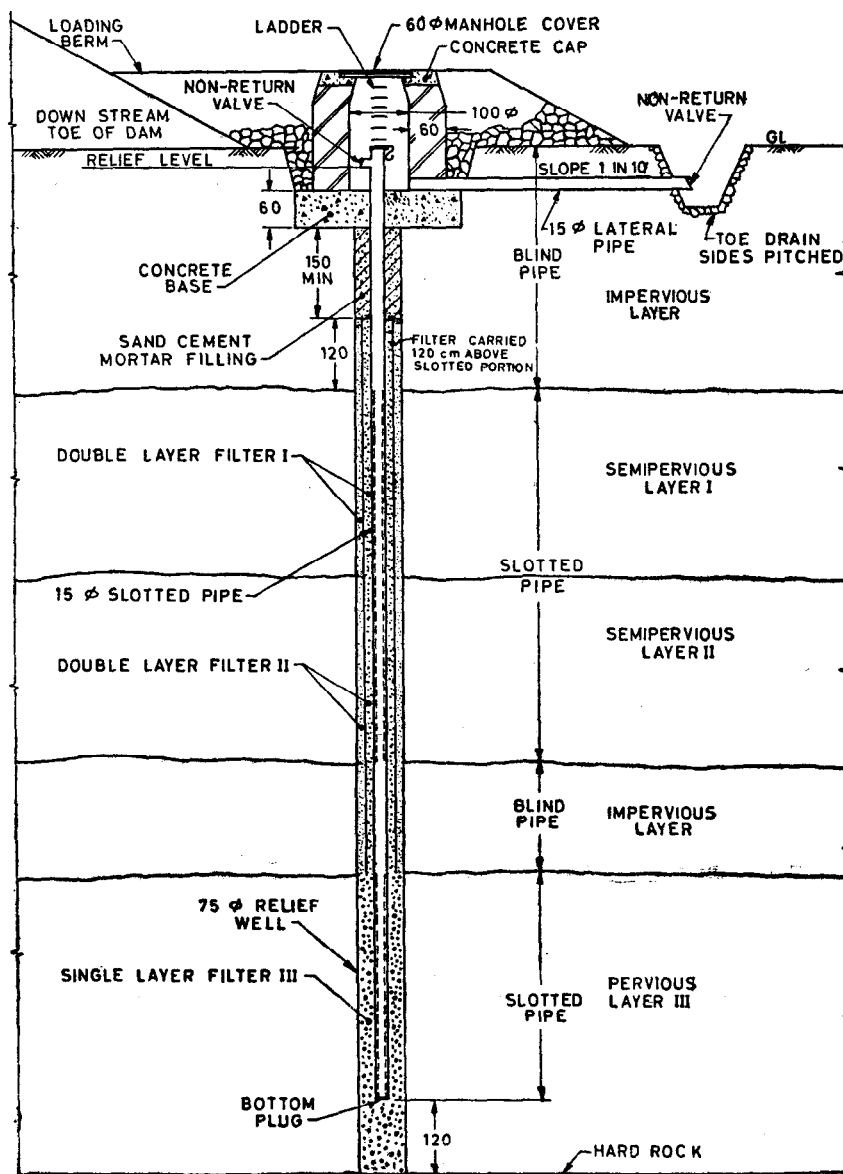
3.5 The relief wells should generally be surrounded and covered by a manhole to facilitate inspection, maintenance and also measurement of discharge from the well.

4 INFORMATION TO BE COLLECTED AT VARIOUS STAGES OF SITE INVESTIGATION

4.1 The information collected during the various stages of investigation of the foundations of a dam could be used for the actual planning and design of a relief well system. It is, therefore, necessary to carry out detailed foundation investigations thoroughly so that the presence of any pervious strata or sand lenses, necessitating special attention, is not missed.

4.2 To decide upon the underseepage control measures to be adopted, field permeabilities of the various substrata under the seat of the dam

should be determined. The *in situ* permeabilities may be determined by the methods described in IS : 5529 (Part 1) : 1985 'Code of practice for *in-situ* permeability test in drill holes: Part 1 Tests in overburden (*first revision*)'. Based on these investigations, the average field permeability of the strata below the dam, may be arrived at. For analysis, stratified anisotropic foundation should be converted into a single layer of isotropic homogeneous material of certain effective permeability. This information along with other data, such as depth of impervious overburden and length may be used for deciding the location, spacing, size, relief levels and depth of penetration of the relief wells.



All dimensions in centimetres.

FIG. 2 TYPICAL INSTALLATION OF A RELIEF WELL

4.3 Whilst carrying out these field investigations, however, care should be taken to detect reaches in which there are preferential paths or concentration of seepage, as these portions would require special treatment, such as closer spacing of relief wells. These preferential paths or concentrated flows may be due to clustering of pervious pockets or may indicate the presence of a subterranean channel which may require special attention. In some cases it may be necessary to even resort to large diameter drilling at close intervals.

4.4 For the final design of the graded filter media to be placed in the relief wells and the dimensions of the slots in the relief pipes dependence will have to be placed on the large diameter holes drilled for the relief wells themselves. Careful sampling should be done at every metre depth, or less, to determine the particle size distribution of the foundation material met at different horizons. From these data, the graded filter media and size of slots may be decided so as to satisfy the desired filter criteria.

5 DESIGN OF RELIEF WELL SYSTEM

5.1 The design of a relief well system for a particular project involves designing and deciding the following:

- a) Location, spacing, size and depth of penetration of relief wells;
- b) Relief levels of individual wells and the drainage system; and
- c) Design of graded filter and slots.

5.2 Location

The relief wells should be located as near the downstream toe of an embankment as possible, the location selected also being suitable from drainage considerations. They may also be provided some distance inwards from the downstream toe, but in such cases, the riser pipes should be taken right to the top of the slope of the embankment or the berm as the case may be, to facilitate surging and air jetting. A berm may be provided at the relief well location to provide overburden as well as to serve as an access road for maintenance and observations (see Fig. 2).

5.3 Spacing, Size and Depth of Penetration of Wells

5.3.1 As there are a number of simplifications involved in the application of the mathematical expression given in 5.3.3, the results obtained should be considered only as a rough guide. Theoretical background and assumptions given in Annex A. It is necessary to install piezometers in between relief wells to measure midway pressure and if the piezometers show high pressures, additional wells should be provided in intermediate positions. In other words, the construction of a

relief well system has to be phased in such a way that the midway pressures are kept down to a minimum so as not to cause any nuisance. Relief wells are commonly spaced at 15 to 30 m centres but shall be provided at closer intervals also, if the situation demands such a measure. In such cases, however, a double line of staggered wells may be provided combined with a downstream loading berm.

Relief wells should normally be planned to penetrate the pervious strata fully, to be most effective. Use of partially penetrating wells can be considered whenever it is established by pumping tests and by multilevel piezometric observations that intermediate impervious layers are absent. In such cases, as a general principle the well penetration should be at least 50 percent of the depth of the principal pervious stratum or equal to the height of the dam, whichever is smaller.

5.3.2 The design of a relief well system consists essentially of determining spacing, size and depth of penetration of relief wells that can reduce the pressure in the substratum, near the toe of the earthen embankment to an allowable head. The allowable head in different sets of condition should be as given in different formulae for designing a relief well system. The well spacing obtained from these formulae should serve as a guide for initial installation. Depending upon the performance of the initially installed system, necessary changes can be made in the relief well system.

5.3.3 For fully penetrating wells (see Fig. 3) following formula can be used to determine midway pressure between two relief wells (h_m).

$$\frac{h_m - h_w}{h_s - h_w} = 1 + \left[\frac{\log_e \frac{2}{1 + \cosh 2j \cdot s}}{2 \log_e \frac{e^{js}}{j \cdot r_w}} \right]$$

where

h_m = midway pressure in m of water in between two relief wells,

h_w = pressure maintained at the relief wells in m of water,

h_s = pressure head at the line drive source in m of water,

$j = \frac{2\pi}{a}$ where a is an spacing of wells in m,

s = distance between line drive source and line wells in m, and

r_w = effective radius of a well in m (usually the distance between centre of filter to centre of the well).

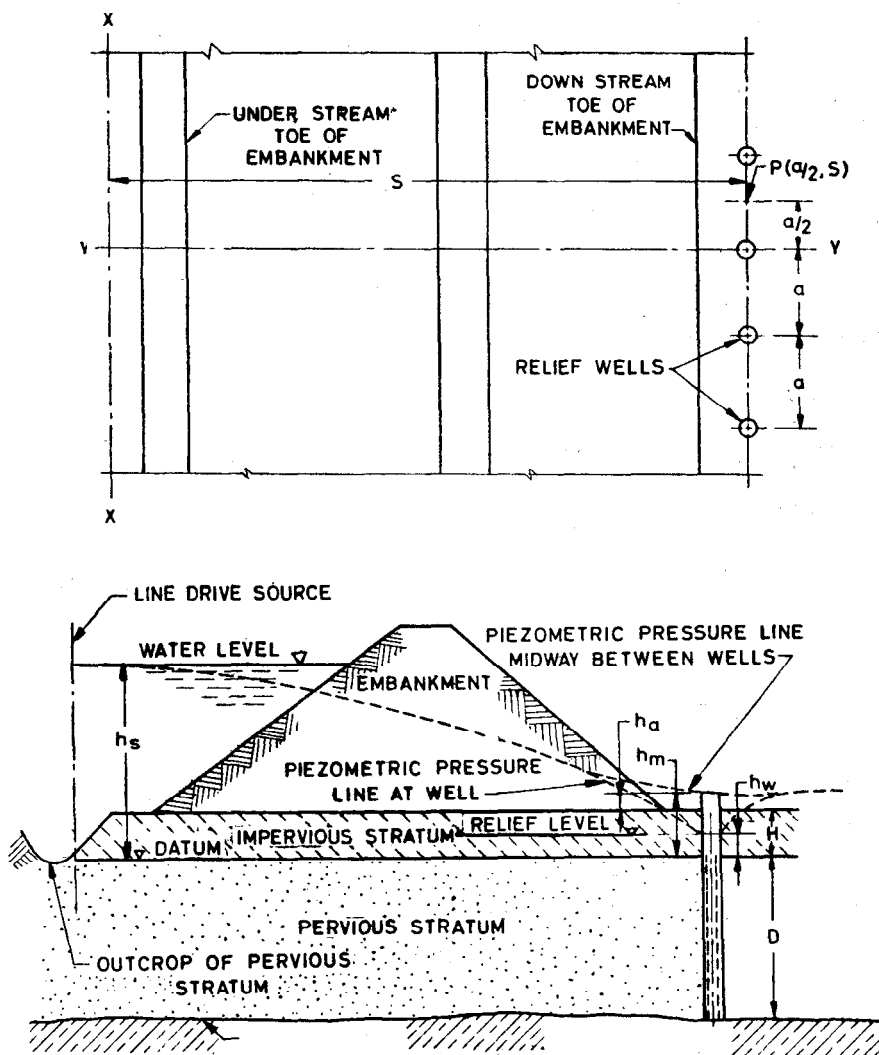


FIG. 3 EMBANKMENT ON PVIOUS FOUNDATIONS FOR MATHEMATICAL ANALYSIS OF RELIEF WELLS (MIDDLE BROOKS AND JERVIS FORMULA)

5.3.3.1 Further, simplifying the above given formula, we get:

$$\frac{h_m - h_w}{h_s - h_w} = \frac{0.693 - \log_e jr_w}{j \cdot s - \log_e jr_w}$$

where all the variables carry the same description as given in 5.3.3. Annex B illustrates use of this formula.

5.3.3.2 Two sets of curves are obtained, using formula given in 5.3.3.1. These sets are presented in Fig. 4A and 4B. The curves in Fig. 4A can be directly utilised for $r_w = 3.0$ cm, and $r_w = 6.0$ cm. These values of r_w approximately correspond to relief well diameters of 10 cm and 20 cm respectively.

The curves in Fig. 4B can be directly utilised for values of r_w equal to 15 cm and 25 cm

corresponding to approximate relief well diameters of 50 cm to 90 cm.

Annex B illustrates use of these charts and formula given under 5.3.3.1 and 5.3.3.2.

5.3.4 For design of partially penetrating relief wells, formula given hereunder may be used:

$$h_m - h_w = P = \frac{h \cdot \theta}{\frac{S}{a} + \frac{E_L}{a}}$$

where

h_m = midway pressure in m of water in between two relief wells;

h_w = pressure maintained at the relief wells in m of water;

h = the net head acting on the well, that is ($h_s - h_w$) in m of water;

- θ = a factor obtained from Fig. 5B;
 S = distance in m from line drive source to row of wells;
 E_L = extra length in m; and
 a = well spacing in m.

The values of $\frac{EL}{a}$ and θ may be obtained from Fig. 5A and 5B. An illustration is given in Annex C.

5.3.5 Alternate to the formulae given under 5.3.4 and curves in Fig. 5A and 5B, following formulae may be used for partially penetrating relief wells:

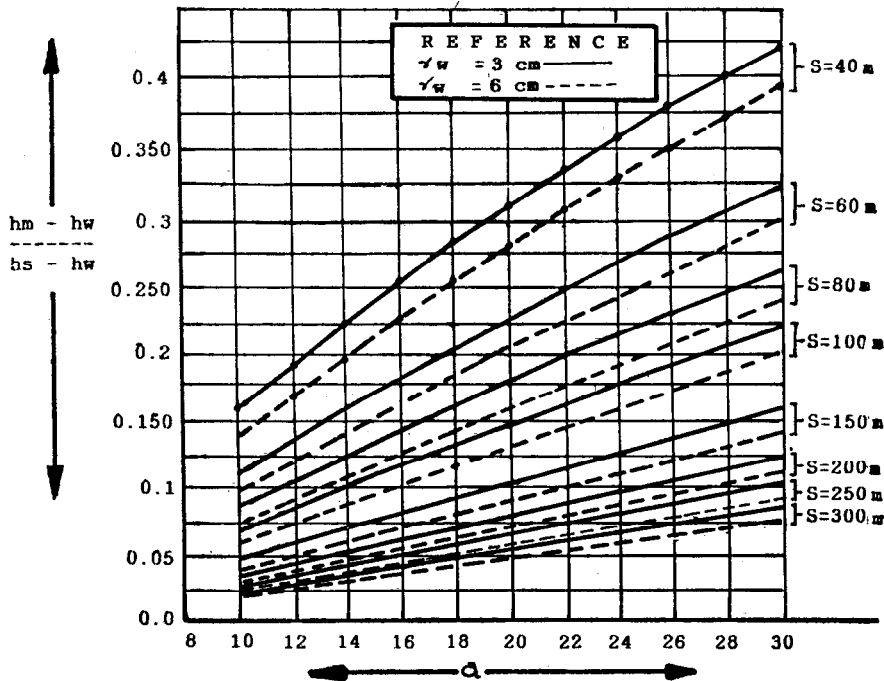
$$Q = KDa (S_u - S_d)$$
$$\frac{h_a KD}{Q} = \frac{h_a}{a (S_u - S_d)} = \frac{D}{2\pi W}$$
$$\log_e \frac{a}{2\pi r_w} + 0.11 \left(\frac{D}{a} - 1 \right) \left(\frac{D}{W} - 1 \right)$$
$$\frac{h_m KD}{Q} = \frac{h_m}{a (S_u - S_d)}$$
$$= \frac{D}{2\pi W} \log_e \frac{a}{2\pi r_w} + 0.11$$

- where
 Q = discharge per well in m³/min,
 K = average horizontal permeability of the pervious stratum in m/min,

- D = depth of pervious stratum in m,
 a = well spacing in m,
 S_u = upstream hydraulic gradient,
 S_d = downstream hydraulic gradient,
 h_a = mean head at the line of wells in m,
 W = depth of well in m,
 r_w = radius of well in m, and
 h_m = head midway between wells in m.

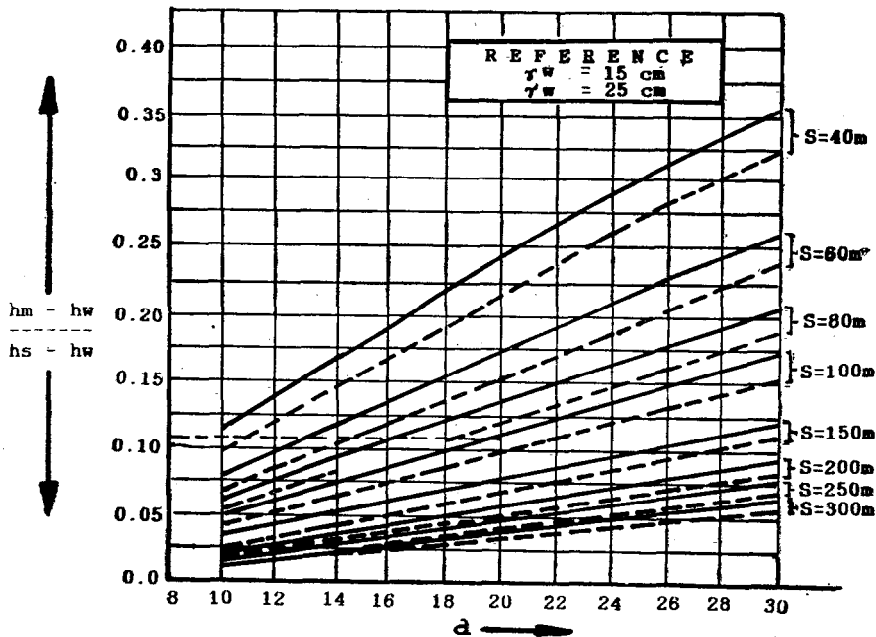
5.3.6 The design of relief well system is an iterative procedure. Initially, certain variables are assigned some arbitrary values. Depending on these values and utilising appropriate formula the value of h_m is worked out.

5.3.6.1 For ensuring safety against uplift, the maximum residual pressure above ground level ($h_m - H$) acting at the base of the impervious stratum should not exceed 0.3 to 0.6 H . The upper limit (0.6 H) should be used for low dams, flood embankments, etc. The lower limit (0.3 H) should be used for high dams and important structures.



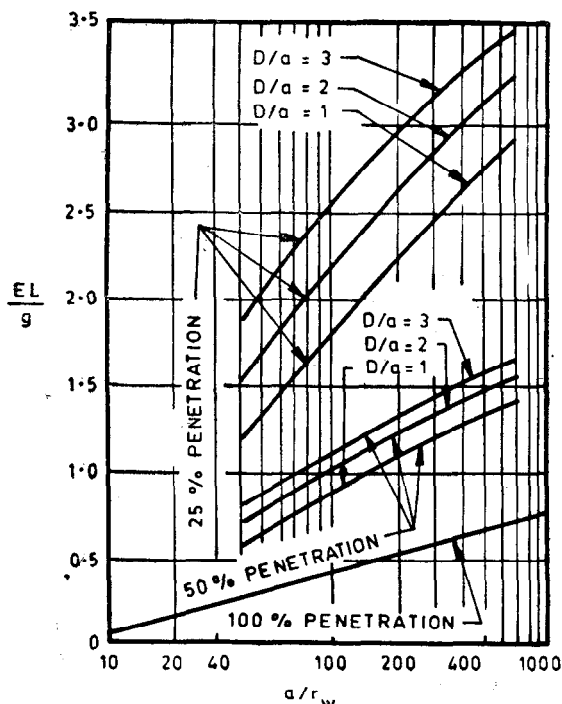
NOTE — This chart should not be extrapolated for $10\text{ m} < a > 30\text{ m}$.

FIG. 4A CURVES FOR $\frac{h_m - h_w}{h_s - h_w}$ VS a FOR $r_w = 3$ AND 6

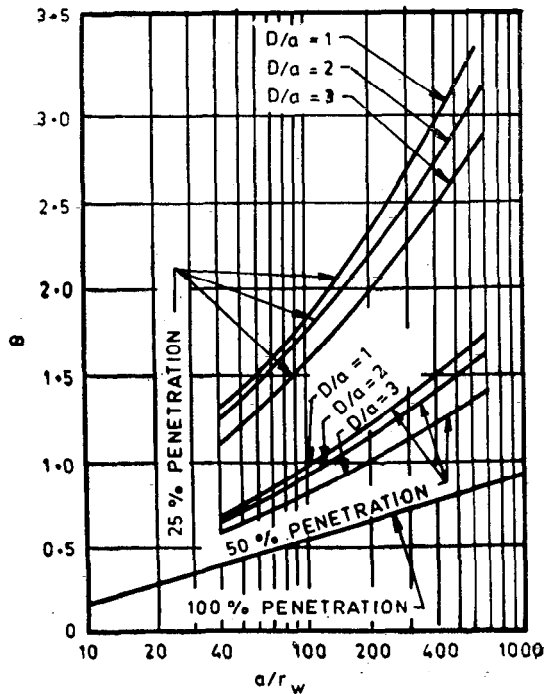


NOTE — This chart should not be extrapolated for $10 \text{ m} < a < 30 \text{ m}$.

FIG. 4B CURVES FOR $\frac{h_m - h_w}{h_s - h_w}$ vs a FOR $r_w = 15$ AND 25



5A Curves for Extra Length, EL



5B Curves for θ

FIG. 5 CURVES FOR E_L AND θ

5.3.6.2 If $(h_m - H)$ exceeds the recommended value, spacing of the relief wells should be reduced until the residual pressure is equal to, or less than the recommended value. While designing the relief wells, frictional and other losses in the wells (see 5.6) should be taken into account.

5.4 Relief Levels of Individual Wells and Drainage System

5.4.1 The discharge level or relief level should normally be kept somewhat below the ground level. It shall also be such that the discharge from the well can be led away by gravity by an economical surface drainage system.

5.4.2 A well-laid-out drainage system should be provided to drain off discharges of the relief wells either into the central gorge or to a NALLA or canal in between, if levels permit. Wherever necessary, non-return valves should be provided to prevent back-water entering the relief wells during floods.

5.4.3 If no cut-off is provided under an earth dam, the discharge from a relief well may be worked out as below:

$$Q = \frac{K h a D}{S + E_L}$$

where

Q = discharge per well in m^3/min ;

K = average coefficient of permeability of the pervious stratum;

h = net head acting on the well, that is $(h_s - h_w)$ in m of water;

a = well spacing in m;

D = depth of pervious stratum in m;

S = distance from line drive source to the line of wells in m; and

E_L = extra length in m found out from Fig. 5A.

5.4.4 A cut off trench or partial cut off with an upstream blanket would reduce the discharge materially. However, the drainage system may be designed by use of formula given in 5.4.3 plus a reasonable safety factor and modified on the basis of observations made (see 9).

5.5 Design of Graded Filters and Slots

5.5.1 The primary requirement of a filter is that it should be so designed and installed as to allow free flow of water into the well. For this, the filter has to be many times more pervious than the foundation base material to effectively drain it. Secondly, the seepage water should not be allowed to transport excessive quantities of fine base material into the well. For this, the filter shall be of such gradation that the base material will not migrate through its voids.

5.5.2 Granular — Graded Filter

To satisfy the requirement of 5.5.1 the following ratios of filter material with reference to base material should be satisfied:

a) Stability ratio $\frac{D_{15} \text{ filter}}{D_{85} \text{ base}} < 4$

b) Permeability ratio $\frac{D_{15} \text{ filter}}{D_{15} \text{ base}} > 4$

c) For circular holes in the central pipe

$$\frac{D_{85} \text{ filter}}{\text{Hole diameter}} \geq 1.5$$

d) For slots in the central pipe

$$\frac{D_{85} \text{ filter}}{\text{Slots width}} \geq 2.0$$

5.5.2.1 A filter satisfying the criteria given in 5.5.2 may still fail if it has an excess, or lack of certain sizes or is not uniformly graded. Hence the following additional criteria shall also be satisfied:

a) The gradation curve of the filter shall be more or less parallel to that of the base material.

b) $\frac{D_{15} \text{ filter}}{D_{15} \text{ base}} < 20$

c) $\frac{D_{50} \text{ filter}}{D_{50} \text{ base}} < 25$

5.5.3 Filter Fabric (Geotextile) and Slots

Synthetic polymeric fabric filters are in use in place of granular graded filters around the perforated polyvinyl chloride (PVC) pipes. The provision of geofabric as filter is found helpful in saving of costs by way of drilling smaller diameter holes.

5.5.3.1 Design of geofabric as filter

There are various filter design criteria in practice:

i) For non-cohesive soils — well graded,

For $C_u > 4$, $\phi_{100} < d_{85}$; and

for $C_u < 4$, $\phi_{100} < 0.8 d_{85}$.

ii) For cohesive soils — Uniform soils — Same rules as given for non-cohesive soils are adopted but minimum ϕ_{100} of 0.05 mm is recommended.

where

C_u = Uniformity coefficient of soil (d_{60}/d_{10})

ϕ_{100} = Equivalent/maximum opening size of geofabrics (100% size of soil retained on it).

d_{85} = Diameter of the base soil particle with 85 percent passing (finer).

The initial normal permeability of geofabrics in uncompressed/unstressed state should be at least ten times that of the soil.

NOTE — The allowance for long-term clogging and reduction in permeability due to effect of confinement is already accounted for in the above criteria.

5.5.4 Material for filters around the strainer pipe should consist of washed sand or gravel, free from any adherent coating, vegetable matter, or elongated particles in quantities considered detrimental.

5.6 Head Losses in Relief Well System

5.6.1 Hydraulic losses due to friction, creation of velocity, sudden changes in pipe dimensions, bends, etc, take place in the strainer pipe, riser pipe and lateral pipe of relief well. These losses result in decrease in head acting on the well and reduce well discharge and consequently increase the midway pressures. Hence all such losses should be estimated and added to the midway pressures calculated by the formulae mentioned in 5.3.3 and 5.3.4 before comparing them with permissible residual pressures.

5.6.2 Head Losses

5.6.2.1 Friction losses may be computed from the following pipe flow formula:

$$h_f = \frac{30.3 V^{1.85}}{C^{1.85} d^{1.167}} \text{ m per 10 m of pipe}$$

where

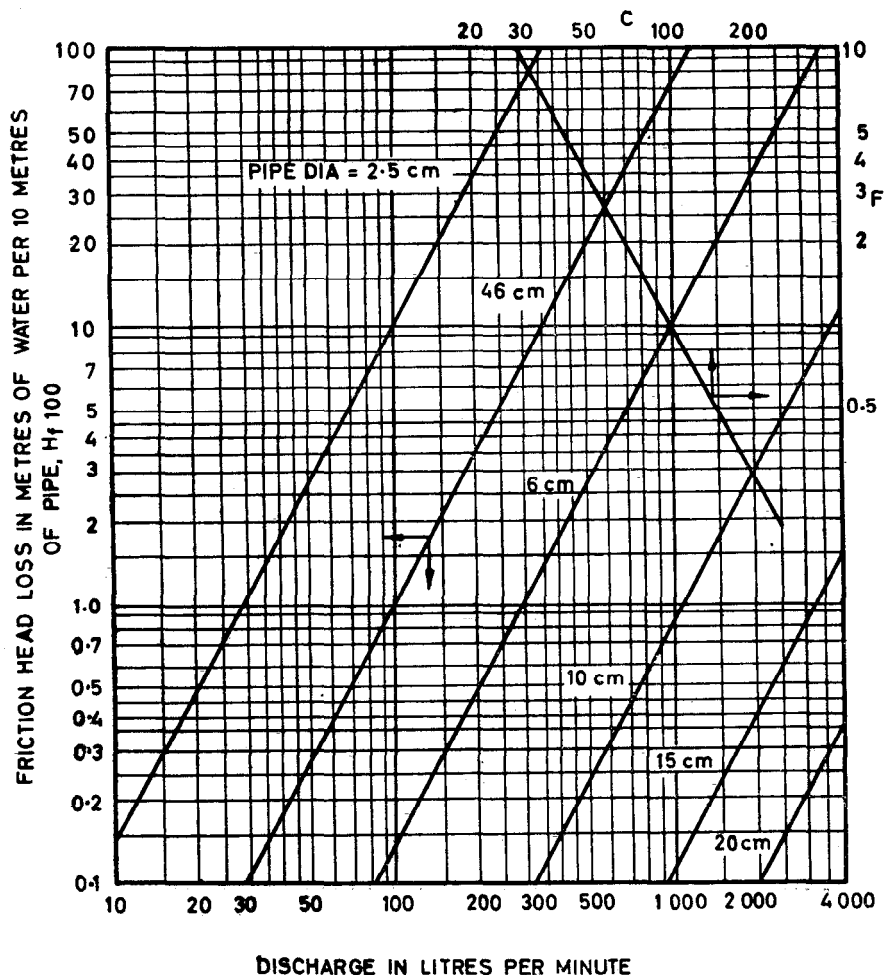
h_f = friction loss in the strainer pipe in m per 10 m of pipe;

V = velocity in m/s;

C = a selected constant depending on the condition of the pipe life, etc; and

d = diameter of the pipe, in m.

Assuming uniform flow through the strainer pipe at various levels, only 40 percent of its total length should be used for friction loss calculations. Solutions of the above equation for $C = 100$ are given in Fig. 6 for various pipe sizes including a curve for obtaining the corrective factor, 'F', to be used for obtaining losses for pipes with 'C' other than 100.



NOTE — For calculating friction losses for pipes with C other than 100, multiply $H_f 100$ found out from above curves by $(100/C)^{1.85}$ or $H_{fe} = F \cdot H_f 100$,

F = Found from above curve.

FIG. 6 FRICTION LOSS IN PIPES BY HAZEN-WILLIAMS FORMULA FOR $C = 100$

5.6.2.2 The velocity head loss should be calculated from the formula (see Fig. 7):

$$h_v = \frac{V^2}{2g}$$

where

- h_v = velocity head in m,
- V = velocity in m/s, and
- g = acceleration due to gravity in m/s².

5.6.2.3 If elbow connections are provided, elbow loss to be considered in design should be calculated from the following formula:

$$h_e = 1.5 \frac{V^2}{2g}$$

where

- h_e = head loss in m,
- V = velocity in m/s, and
- g = acceleration due to gravity in m/s².

6 INSTALLATION OF RELIEF WELLS

6.1 After deciding on the location of relief wells, the installation should be made in steps indicated in 6.2 to 6.4. It is not always feasible,

to drill holes of 50 to 90 cm diameter. The constraint may be either due to non-availability of the equipment or hard intermediate strata or space around the riser pipe.

6.2 GI-Pipe Relief Well

6.2.1 Holes of 50 to 90 cm diameter should be drilled, usually by driving a casing pipe, and the inside material bailed or chiselled out.

6.2.2 At every metre depth, foundation soil samples should be taken out by suitable samplers or bailers and mechanical analysis done on these samples.

6.2.3 GI pipes 10 to 15 cm in diameter should be slotted as designed. It should be seen that the slots or holes cover about 10 percent of the circumferential area of the pipe. Vertical slotting is preferable to horizontal. The GI pipes should be coated by anti-corrosive paint or regalanized after slotting.

6.2.4 Certain depths of foundation strata may be grouped together according to gradation and for each such group, filters satisfying the design criteria should be prepared.

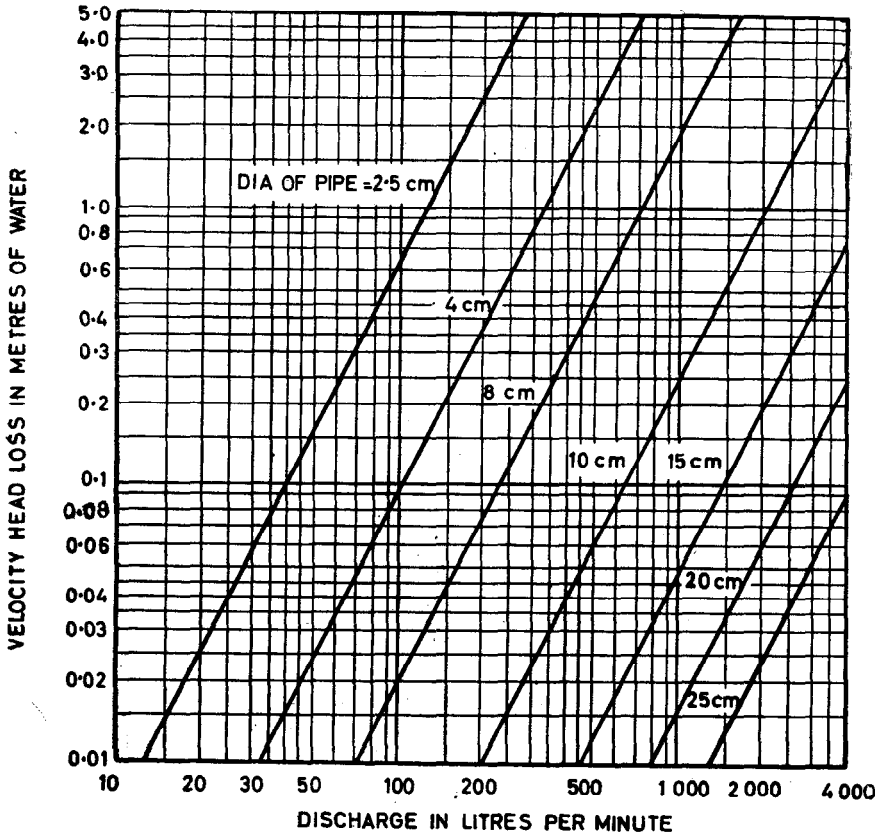


FIG. 7 VELOCITY HEAD LOSS IN PIPES

6.2.5 The slotted pipe should then be centred and the filter material poured carefully to a predetermined level through a tremie to avoid segregation. The top of the filter should then be plugged by cement-sand mortar or a clay plug or a mixture of sand with about 10 percent bentonite.

6.2.6 Later on, a suitable masonry well with cover should be built up around the relief well. The relief well should also be connected to the surface drainage system.

6.3 Rigid PVC Pipe Relief Well

After deciding the location of relief wells, the installation should be made in the steps as indicated in 6.3.1 to 6.3.8.

6.3.1 Holes of 50 to 90 cm diameter should be drilled usually by driving casing pipe and the inside material boiled or chiselled out.

6.3.2 At every metre depth, foundation soil samples should be taken out by suitable samplers or bailers and mechanical analysis done on these samples.

6.3.3 PVC screen pipes should have vertical slots, with 10 percent open area of the circumferential area of the slotted length of pipes. Vertical slots are preferable to horizontal slots.

6.3.4 The granular layer may be either omitted or placed around the PVC-slotted pipe wrapped round with a suitable geofabric. Any granular material available at the site should be placed around the screen. (Its gradation can be relaxed and it can be finer than those required as per filter-design criteria) but adequately coarse as required by the criteria suggested in 5.5.3.

6.3.5 The slotted pipe should be wrapped round, with a geofabric which should fulfil the filter design criteria given in 5.5.2. The geofabric should be wrapped round the pipe spirally with an overlap of 20 cm. The width of geofabric can be narrow but should not be less than 100 cm. The geofabric should be tried with the rigid PVC pipe using GI wire such that it does not wrinkle or slip down while being lowered into a borewell.

6.3.6 The slotted pipe should then be centred and the granular material should be poured carefully to a predetermined level, through a tremie-pipe, the top annular space around the pipe shall then be plugged by cement-sand mortar or a clay-plug or a mixture of sand with 10 percent bentonite.

6.3.7 Later on, a suitable masonry wall with a cover should be built up around the relief well.

6.3.8 The relief well should be connected to the surface drainage system.

6.4 In case of use of geofabric as filter media the slotted pipe should be spirally wrapped round with the geofabric material with sufficient overlapping. The width of geofabric should not be less than 100 cm. To prevent slippage of geofabric over the pipe, while lowering inside the hole, it should be properly tied with the pipe using plastic/nylon cord. The geofabric wrapped slotted pipe should then be carefully lowered inside the drilled hole. The annular space left between the pipe and the hole should be filled with clean fine sand or any granular material, up to 1.0 m above the relief level. The plugging of the hole should then be done as per 6.2.5 above.

7 DEVELOPMENT OF FILTER AROUND SLOTTED PIPE OF RELIEF WELLS

7.1 General

After the relief wells are installed, it is necessary to develop the filters around the slotted pipes of the relief wells to ensure that the wells drain out the aquifer efficiently. The following operations are to be carried out to develop the wells:

- Surging the wells by means of a surge block and pumping out the dirty water;
- Air jetting the wells at suitably low pressures to clean the filter, remove debris, etc; and
- Determination of specific capacity by pumping-out test.

7.2 Surging of the Relief Wells

Surging of the wells may be carried out by a wooden block slightly smaller in diameter than the slotted pipe. A sketch of the surge block for a 15 cm internal diameter well is shown in Fig. 8 for guidance.

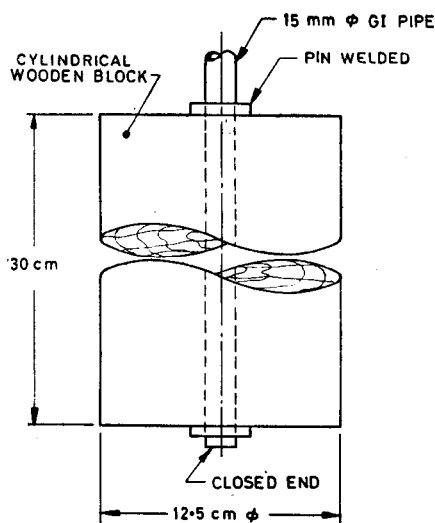
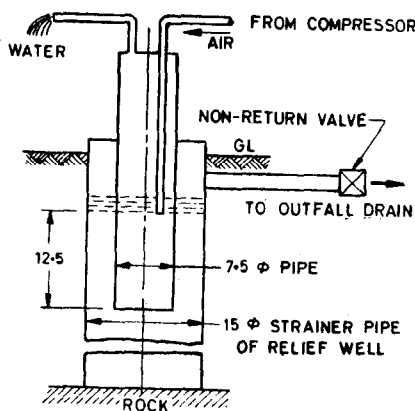


FIG. 8 SURGE BLOCK FOR A 15 cm INTERNAL DIAMETER RELIEF WELLS

7.2.1 The surging operation consists of churning up water in the relief well by up and down movements of the block. The surge block should be raised and lowered at the rate of approximately 1.5 m/s. Surging should be done for each metre layer (for a few minutes) from bottom upwards for the slotted portion of the relief well and thereafter dirty water should be pumped out till clear water emerges. If the depth of the well is considerable, surging and pumping may be done alternately for suitable lengths.

7.3 Air Jetting of Relief Wells

After surging and pumping as in 7.2, the relief wells should be air and water jetted by an appliance as shown in Fig. 9. Jetting should be done from bottom to top of slotted portion of the well by lifting the appliance about 30 cm each time. Air jetting for each lift should be continued for about 5 to 10 minutes or until clean water emerges. The results of these operations should be recorded in the proforma given in Annex D.



All dimensions in centimetres.

FIG. 9 SET UP FOR AIR AND WATER JETTING RELIEF WELLS

7.4 Pumping Tests and Determination of Specific Capacity

7.4.1 Immediately after surging and jetting, a pumping test should be conducted to determine the rate of inflow and the rate of sand infiltration. The pumping test should be conducted for at least half an hour by a pump of adequate capacity and the specific capacity (rate of flow in litres per minute, per metre depth of draw-down) may be determined after taking at least three measurements of discharge consecutively, all of which should nearly be equal. This condition will be realized only after a steady state condition of discharge is reached. The draw-down during pumping at steady state should not exceed 1.5 m depth and not less than 0.5 m.

7.4.2 Measurements made during this test should be recorded in the proforma given in Annex E and the specific capacity of each well, just after installation, should be available to compare the performance of the relief well with passage of time.

7.4.3 During pumping test the water pumped out should be passed through a stilling tank, suitably baffled to cause any fine sand in the water to settle out and the quantity of sand collected measured. This quantity is an indication of filter efficiency. Similarly a few samples of water discharged by relief wells should be collected and chemical and sedimentation analysis carried out.

8 MAINTENANCE OF RELIEF WELLS

8.1 Each year before the onset of monsoon (say in April-May), the blocked depth of each well should be checked with reference to original depth and if the blocked depth has increased substantially, say more than 60 cm, the well should be cleaned by surging, jetting and pumping as in 7.2 and 7.3. Soundings should be taken both before and after jetting to ascertain the depth to which the well is cleaned and the readings should be recorded in the proforma given in Annex D.

8.2 Surging and jetting should normally restore the capacity of the well. However, each well in which excess sediment is noticed should be pump tested to its specific capacity. If the specific capacity is found to be less than 80 percent of the original capacity, re-jetting will be necessary to restore the desired specific capacity.

8.3 Surging and jetting should also be done using chemicals like sulphamic discalent (i.e. mild organic-acid) which will help in removing incrustation of slotted pipe relief well.

8.4 After a few years the slotted metal pipe may erode and the filter material may start flowing in the well. The well may then have to be replaced by a new relief well, a few metres away from it.

8.5 The non-return valves should be inspected each year to check their working and cleaned and repaired if found necessary.

9 OBSERVATIONS

9.1 Piezometers should be installed to check the pressures that still prevail midway between the relief wells. At times, the relief wells may also be used to measure the hydrostatic head at the relief well by closing the overflow pipe. Regular observations of piezometers especially during high water should be maintained.

9.2 Detailed instructions for observing discharges through relief wells are given in Annex F. The overflow from each relief well shall be recorded in the proformae given in Annex G, and Annex H and relevant lake levels should be noted. This data would give a clear picture as

to the elevation of upstream water level at which a particular relief well comes into operation and below which level it simply functions as a piezometer. By studying records of successive years, efficiency of the installations can be evaluated.

ANNEX A

(Clause 5.3.1)

THEORETICAL BACKGROUND AND ASSUMPTION INVOLVED IN SIMPLIFYING THE DESIGN PROCEDURE OF RELIEF WELL SYSTEM

A-1 The design of a relief well system consists essentially of determining the spacing, size and depth of penetration of the wells that will reduce the substratum pressure at the toe of an embankment to an allowable head. Due to large variation in foundation characteristics, it would be difficult to estimate accurately the pressure distribution under an embankment and unless the existing conditions are deduced, a mathematical solution would not be possible. Nevertheless, it is necessary to estimate roughly the required spacing of relief wells. An acceptable mathematical solution has been obtained for a line of equally spaced wells fully penetrating the pervious strata in artesian conditions and fed by a line drive source. This formula makes the following assumptions:

- Infinite line drive source,
- Infinite line of equally spaced wells,
- Infinite extent of pervious stratum,
- The pervious stratum is completely saturated and the top stratum is impervious,
- The pressure reduction due to travel of seepage from the line drive source to the relief wells is neglected, and
- The pervious stratum is homogeneous and isotropic.

A-2 An embankment resting on pervious foundations satisfying the conditions mentioned in **A-1**, depth of the pervious stratum being 'D' overlain by an impervious stratum of thickness 'H' and row of wells spaced at a distance 'a' from each other, fully penetrating the pervious stratum and at a distance 's' from the line drive source is shown in Fig. 3. If ' h_w ' is the head (datum is usually taken at the top of pervious stratum) maintained at the wells, then ' h ', the head at line drive source is reduced to ' h_m ' at a midpoint between the wells. To decide the value of ' h_m ' formulae specified under 5.3.3 and 5.3.3.1 may be utilised.

A-3 Relief wells should normally be planned to penetrate the pervious stratum fully, to be most effective. Use of partially penetrating wells can be considered whenever it is established by pumping test and by multilevel piezometric observations that intermediate impervious layers are absent. In such cases, as a general principle the well penetration should be at least 50 percent of the depth of the principal pervious stratum or equal to the height of the dam, whichever is smaller. For designing partially penetrating wells, formulae given in 5.3.3 and 5.3.4 may be utilised in conjunction with curves given in Fig. 5.

ANNEX B

(Clause 5.3.3 and 5.3.3.1)

AN ILLUSTRATION OF USE OF FORMULA GIVEN IN 5.3.3 AND CURVES GIVEN IN FIG. 4A AND 4B

In the Fig 10, assume:

$$S = 100 \text{ m.}$$

$$H_s = 12 \text{ m.}$$

$$H = 3 \text{ m.}$$

To design a relief well system with these data, assume:

$$r_w = 15 \text{ m.}$$

$$h_w = 1 \text{ m and initial spacing of relief well.}$$

$$a = 20 \text{ m.}$$

With these assumptions we can find out h_m by either utilising the formula given under 5.3.3 or 5.3.3.1 or curves given in Fig. 4B.

First,

a) using formula given under clause 5.3.3.

$$j = \frac{2\pi}{a} = \frac{2 \times 3.143}{20} = 0.3143.$$

$$\therefore \frac{h_m - h_w}{h_s - h_w} 1 + \left[\frac{\log_e \frac{2}{1 + \cos h 2 j_s}}{2 \log_e \frac{e j_s}{j r_w}} \right] = 0.108 6$$

$$\frac{h_m - 1}{12 - 1} = 0.108 6$$

$$h_m = 2.194 6 \approx 2.2 \text{ m}$$

Now $h_m - H = 2.2 - 3.0 = -0.8 \text{ m}$
which is less than 0.34

Hence $a = 20 \text{ m}$ is satisfactory.

b) using formula given under 5.3.3.1.

$$j = \frac{2 \pi}{a} = \frac{2 \times 3.143}{20} = 0.314 3$$

Now,

$$\frac{h_m - h_w}{h_s - h_w} = - \frac{0.693 - \log_e j r_w}{j_s - \log_e j r_w}$$

$$\therefore \frac{h_m - 1}{12 - 1} = 0.108 7$$

$$\therefore h_m = 2.195 7 \text{ m} \approx 2.2 \text{ m}$$

$\therefore h_m - H = 2.2 - 3.0 = -0.8 \text{ m}$ which is less than 0.3 H .

$\therefore a = 20 \text{ m}$ is O.K.

c) Using curves given in Fig. 4B

Using curve for,

$$r_w = 15 \text{ cm and } S = 100 \text{ m.}$$

at $a = 20 \text{ m}$

$$\frac{h_m - h_w}{h_s - h_w} = 0.108 8$$

$$\therefore \frac{h_m - 1}{12 - 1} = 0.108 8$$

$$\therefore h_m = 2.196 8 \text{ m} \approx 2.2 \text{ m}$$

$\therefore h_m - H = 2.2 - 3.0 = -0.8 \text{ m}$ which is less than 0.3 H

$\therefore a = 20 \text{ m}$ is O.K.

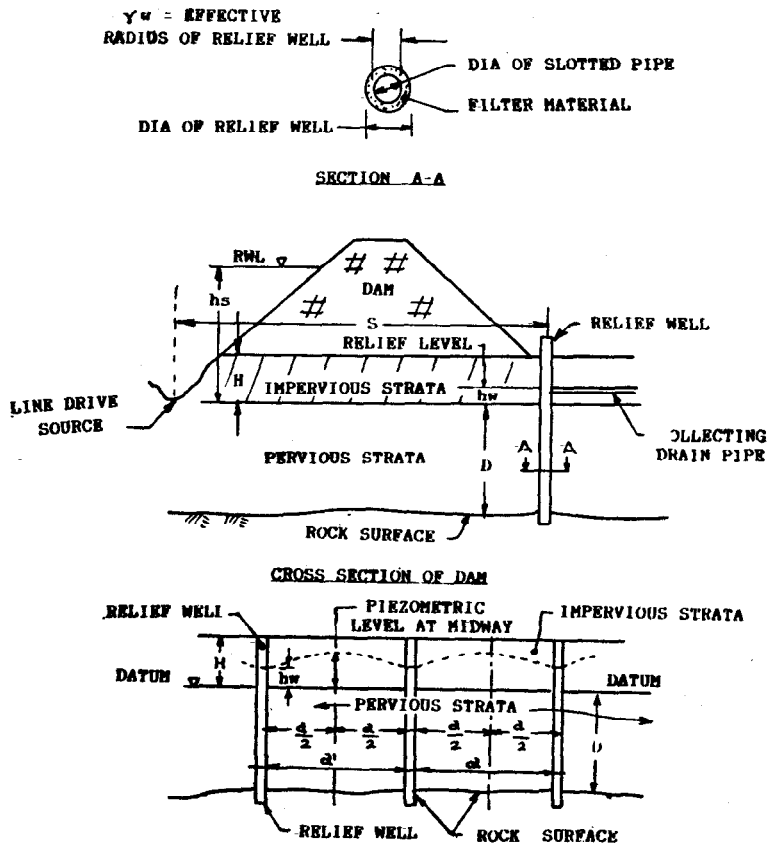


FIG. 10 ROW OF RELIEF WELLS

ANNEX C

(Clause 5.3.4)

AN ILLUSTRATION FOR USE OF FORMULA GIVEN UNDER CLAUSE 5.3.4 AND CURVES IN FIG. 5A AND 5B

Consider Fig. 5A and assume that

$$\begin{aligned} D &= 40 \text{ m} \\ H &= 5 \text{ m} \\ H_s &= 35 \text{ m} \\ \text{and } S &= 100 \text{ m} \end{aligned}$$

To design a relief well for this situation we can assume as follows:

$$\begin{aligned} r_w &= 0.25 \text{ m} \\ w &= 20.0 \text{ m (50 percent penetration)} \\ a &= 20.0, \\ \text{and } h_w &= 2.0 \text{ m} \\ \therefore \frac{a}{r_w} &= \frac{20.0}{0.25} = 80 \\ \text{and } \frac{D}{a} &= \frac{40.0}{20.0} = 2 \end{aligned}$$

$\therefore$ From Fig. 5A for 50 percent penetration

$$\begin{aligned} \text{and } \frac{D}{a} &= 2 \\ \frac{E_L}{a} &= 0.9 \text{ for } \frac{a}{r_w} = 80 \end{aligned}$$

From Fig. 5B for 50 percent penetration, and

$$\frac{D}{a} = 2 :$$

$$\theta = 0.8 \text{ for } \frac{a}{r_w} = 80$$

As per 5.3.4

$$\begin{aligned} P &= h_m - h_w = \frac{h\theta}{\frac{s}{a} + \frac{-E_L}{a}} \\ h_m - 2 &= \frac{(h_s - h_w) \theta}{\frac{S}{a} + \frac{E_L}{a}} \\ &= \frac{(35 - 2) \times 0.8}{\frac{100}{20} + 0.9} \\ &= \frac{33 \times 0.8}{5.9} \\ &= 4.47 \\ \therefore h_m &= 6.47 \text{ m} \\ \therefore h_m - H &= 6.47 - 5.0 = 1.47 \text{ m} \\ &\quad \text{which is less than } 0.3 H \\ \therefore a &= 20 \text{ m is O.K.} \end{aligned}$$

ANNEX D

(Clauses 7.3 and 8.1)

STATEMENT SHOWING THE TOTAL DEPTHS OF RELIEF WELLS BEFORE AND AFTER AIR JETTING

Sl No.	Location	Top Reduced Level of Pipe	Bottom Reduced Level	Total Depth	Depth Before Jetting	Initial Filling	Depth After Jetting	Residual Filling
		m	m	m	m	m	m	m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*1	600	372.52	353.25	19.27	18.67	0.60	18.85	0.42

*Example for filling of statement.

ANNEX E

(Clause 7.4.2)

PUMP TEST DATA

<i>Sl No.</i>	<i>Location of Well</i>	<i>Date of Installation</i>	<i>Date of Pump Test</i>	<i>Duration of Pumping</i>	<i>Discharge in l/min</i>	<i>Original Level</i>	<i>Drawdown Minutes</i>	<i>Lake Level</i>	<i>Specific Capacity (Discharge per Metre Depth Draw)</i>
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

*Chemical and sedimentation analysis of water from relief wells may be done, where considered necessary.

ANNEX F

(Clause 9.2)

INSTRUCTIONS FOR OBSERVING DISCHARGES THROUGH RELIEF WELLS

F-1 GENERAL

F-1.1 Discharge observations of relief wells should be made on a 'V' notch or by measuring time required to fill a drum or container of known volume.

F-2 INTERVAL OF OBSERVATIONS

F-2.1 The discharge measurements should be made weekly for a few years after the completion of the dam. Once the period of heavy discharge is marked by studying this data, then a fortnightly record should be kept for the periods of low discharges while for high discharge periods, the discharge measurements should be done once a week. For no discharge spells, a fortnightly record of water levels in the relief wells should be maintained.

F-3 RECORD OF OBSERVATIONS IN PROFORMA GIVEN IN ANNEXES G AND H

F-3.1 All the initial observations should be recorded in proforma given in Annex G and H.

F-3.2 When the wells are not discharging, only water levels in them should be recorded in col 5 of the proforma given in Annex G.

F-3.3 Even when the wells are discharging it is necessary to know the residual head of the seepage water. This is found by closing the overflow valve (or relief valve) and noting the level to which water rises in the vertical stem of the well; an extension pipe may be added if found necessary. Only one well should be closed at a time, as closing all wells simultaneously would prove dangerous. Such observations should be done only once in a

month when the wells are discharging and these should be recorded in col 5 of proforma in Annex G in red ink. In addition at a few selected locations (preferably midway between two relief wells) some stand-pipes should be installed. The observations in stand-pipes should be recorded in col 1, 2, 3, 5 and 7 in the proforma in Annex G and col 1, 2, 3, 4 and 6 in the proforma in Annex H in addition to the required information at the top of the proforma.

F-3.4 Proforma given in Annex G should be included by a general layout drawing of relief wells.

F-3.5 A separate register shall be maintained as given in Annex H to indicate the behaviour of a particular relief well on different dates. This register should include a concise record of all details pertaining to the well, such as reasons for providing relief wells, sub-soil strata in which the well is installed, details of slotted pipes and filters used, drawings of installation, photographic record if any, date of installation, cost of each well, name of supplier, etc.

F-4 OBSERVING PERSONNEL

F-4.1 The routine observations should be made by a junior engineer or an overseer, and periodical check observations should be made by the subdivisional officer bimonthly.

F-5 PERIODICAL SUBMISSION OF DATA

F-5.1 Data collected in proformae given in Annex G and H shall be compiled in the division and forwarded periodically to the concerned design authorities.

ANNEX G(*Clauses 9.2, F-3.1 to F-3.4 and F-5.1*)**PROFORMA FOR RELIEF WELLS DISCHARGE MEASUREMENTS**

Dam:

Project:

Date of observations:

Reference drawing No.:

Observed by:

Lake water level:

Name:

Tail water level:

Designation:

<i>Relief Well No. or Stand Pipe No.</i>	<i>Location of the Relief Well or Stand Pipe</i>	<i>Ground Level at the Location of the Well or Stand Pipe</i>	<i>Relie Level</i>	<i>Water Level in the Relief Well or Stand Pipe</i>	<i>Discharge Through the Well in l/min</i>	<i>Remarks</i>
(1)	(2)	(3)	(4)	(5)	(6)	(7)

ANNEX H(*Clauses 9.2, F-3.1, F-3.5 and F-5.1*)**REGISTER OF RELIEF WELL DISCHARGE MEASUREMENT**

Dam:

Relief well No.

Stand pipe No.

Project:

Location:

Reference drawing No.:

a) Drainage

b) Offset from ground level of dam

Ground level of well:

Ground level at stand pipe:

Relief level:

<i>Date</i>	<i>Lake Water Level</i>	<i>Tail Water Level</i>	<i>Water Level in the Well or Stand Pipe</i>	<i>Discharge Through the Well in l/min</i>	<i>Remarks</i>
(1)	(2)	(3)	(4)	(5)	(6)

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